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ABSTRACT

A nearly complete articulated head (including pectoral and pelvic girdles and fins) was collected from an Early Pleistocene, upper bathyal, volcanic ash deposit on Tambac Island, Northwest Central Luzon, Philippines. The specimen was positively identified because of its general resemblance to other large marlins and by its rigid pectoral fin, a characteristic feature of the black marlin. This is the first fossil billfish described from Asia and the first living species of billfish positively identified in the fossil record.

The geographic distribution of the two living species of *Makaira* is discussed. Except for fossil localities bordering the Mediterranean Sea, the distribution of fossil post-Oligocene istiophorids roughly corresponds to the distribution of living adult forms.

During June 1980, we (Fierstine and Welton, in press) collected a large fossil billfish discovered on the property of Pacific Farms, Inc., Tambac Island, near the barrio of Zaragoza, Bolinao Peninsula, Pangasinan Province, Northwest Central Luzon, Philippines (Fig. 1). In addition, associated fossils were collected and local geological outcrops were mapped. The fieldwork continued throughout the month and all specimens were brought to the Natural History Museum of the Los Angeles County for curation, preparation, and distribution to specialists for study.

The fieldwork was important because no fossil bony fish had ever been reported from the Philippines (Hashimoto, 1969), fossil billfishes have never been described from Asia (Fierstine and Applegate, 1974), a living species of billfish has never been positively identified in the fossil record (Fierstine, 1978), and no collection of marine macrofossils has ever been made under strict stratigraphic control in the Bolinao area, if not in the entire Philippines.

The purpose of this study is to briefly describe the geology of the site, identify and describe the fossil billfish, and to give an overview of the zoogeography of istiophorid billfishes.

MATERIALS

All fossil Foraminifera, fish otoliths, and invertebrates collected during this study are property of the Natural History Museum of Los Angeles County and have been sent to specialists for study. The marlin fossil is property of the National Museum of the Philippines in Manila and will be returned there for final disposition.

Recent osteological material was compared with the fossil specimen. The species, length, locality, collection number and kind of material are as follows: *Makaira indica*, 2,195-mm fork length, off Cairns, Australia, HLF-106, complete skeleton; *M. indica*, length unknown, locality unknown, UCLA S551, complete vertebral column and neurocranium; *M. indica*, 2,100-mm fork length, off Kailua-Kona, Hawaii, HLF-112, preserved head; *Makaira nigricans*, 3,280-mm fork length, Indian Ocean, BRUNN 565-60, complete skeleton; *M. nigricans*, length unknown, off Kailua-Kona, Hawaii, HLF-110, partial neurocranium; *M. nigricans*, 2,060-mm fork length, off Kailua-Kona, Hawaii, HLF-111, preserved head.

Abbreviations for catalogue members of examined material are: BRUNN—Anton Brunn cruise (National Museum of Natural History). HLF—personal collection of one of the authors, UCLA—University of California, Los Angeles.
Geological Setting

The fossil marlin was found in the lower portion of a series of 29 nearly horizontal lithologic units or facies (Fig. 2) on Tambac Island and these units represent approximately 33 m of vertical stratigraphic section. Each sequence is usually composed of a basal dark, resistant, silty-sandstone unit, a few inches to 2 feet thick and an overlying thicker, less resistant, siltstone unit. Either or both may be fossiliferous and laminated, or extensively bioturbated. We interpret these units as turbidites (Fierstine and Welton, in press).

According to Johanna Resig (letters dated 2 and 5 November 1981, University of Hawaii at Manoa) who is studying the Foraminifera of Tambac Island, the marlin bearing layer is Early Pleistocene and was deposited in water slightly deeper than 300 m or upper bathyal. This layer contains a large amount of volcanic ash that resulted from an arc-type volcano. In contrast to some of the layers above and below the fossil marlin, it does not contain many foraminifera displaced from shallow water (turbidites commonly contain a mixture of shallow and deep water organisms). Resig attributes the excellent preservation of the marlin to rapid burial under a rain of ash rather than a turbidite.

The sediments exposed on Tambac Island presumably belong to the Hubay Group, Cabatuan Formation, and possibly the Margaret Sandstone member (Grey, 1967). The only general work on the Pangasinan Province (Anonymous, 1974) does not use lithostratigraphic names.

**Makaira indica** (Cuvier) 1831

*Figures 3–6*

Identification. — The specimen is assigned to *Makaira* because of its large size and its acute parasphenoidal angle. The other two genera of istiophorids, *Istiophorus* and *Tetrapturus*, tend to be much smaller and have a more obtuse parasphenoidal angle (Fierstine, 1978). It is assigned to *M. indica* (black marlin) rather than to *M. nigricans* (blue marlin) because the structure of the pectoral fin signifies that it is non-depressible or rigid, a widely accepted diagnostic feature for the black marlin (Nakamura, 1974). The specimen is not assigned to the extinct *M. panamensis* (Late Miocene of Panama) because features that characterize *M. panamensis* (ventral border of orbit/postrostral length, shape of basioccipital foramen, shape and position of nutrient canals in rostrum) cannot be accurately measured.
Figure 2. Stratigraphic section of Tambac Island, Pangasinan Province, Northwest Central Luzon, Philippines. Numbers to the left of column give depth of each unit in feet and inches, and numbers to the right give locality number for each collection. Column on right is continuous with and located below column on left. Martin site is indicated as locality 11.5.
or observed in the Philippine fossil. The nature of the pectoral fin is not known for *M. panamensis*.

**Description and Comparison with Other Forms**

The specimen was oriented in situ in such a way that it was protruding from the cliff head first and dorsal side up. On separate occasions amateurs had collected these parts that eroded first, i.e., rostrum, followed by the neurocranium and ventral hyoid region. Although some of these parts were saved, they were damaged due to handling or exposure to the weather. A locked shed had been built around the remaining fossil to protect it from vandals and weather. We excavated the remainder of the head and the pectoral and pelvic girdles and fins. No vertebrae or remains of other fins were found. Bones excavated at different times would not connect with one another because intervening segments had been lost.

**Hyoid Apparatus and Branchiostegal Rays.**—The hyoid bones are massive, but very incomplete (not figured). The left side consists of a partial epihyal, a partial ceratohyal, the proximal portion of two branchiostegal rays, and the distal portion of three branchiostegal rays. The right side contains an epihyal (that is mostly covered by overlying bones), a partial ceratohyal, a ventral hypohyal, and seven branchiostegal rays (Figs. 3 and 4) which range in shape from the slender first ray to the seventh which is broad and spatulate. The seventh branchiostegal measures 38 mm at its greatest width and 245 mm in length. The urohyal is poorly preserved and is approximately 270 mm long.
Figure 4. Right lateral view of throat and cheek region (with pectoral and pelvic fins) of black marlin (*Makaira indica*), Early Pleistocene, Tambac Island, Philippines. Scale equals 5 cm. Letters indicate: articular (A), dorsal process of coracoid (DCO), gill rays (G), interoperculum (IO), posterior dorsal process of cleithrum (PC), preoperculum (PO), quadrate (Q), supracleithrum (SC), suboperculum (S).

**Lower Jaw, Suspensorium and Opercular Bones.**—The right quadrate-articular joint and adjoining bony parts are well-preserved (Fig. 4). The anterior head of the left hyomandibula, the proximal portion of both maxillaries, and the anterior tips of the palatines articulate with the neurocranium (Fig. 6). The opercular series is represented by the ventral portion of the right preoperculum and a nearly complete right interoperculum and suboperculum (Fig. 4).

**Neurocranium and Sclerotic Bone.**—The neurocranium is so badly worn and fragmentary that only general features can be seen and few meaningful measurements can be made (Fig. 6). It is 209 mm wide between the mid-dorsal margin of the orbits and 355 mm long from the anterior edge of the vomer to the posterior margin of the basioccipital. However, these are very approximate measurements because the dorsal margin of the left orbit, the anterior extension on the vomer, and the posterior limit of the basioccipital are not preserved. The exact parasphenoidal angle (approx. 15°) and the shape of the basioccipital foramen cannot be determined because the posterior part of the parasphenoid and the ventral part of the basioccipital are missing.

The shape of the myodome could not be determined because it was filled with matrix so hard that all preparation techniques available to us failed to remove it. The oval left sclerotic bone is nearly complete and is 104 mm across its elongate antero-posterior axis and 91 mm across its dorso-ventral axis. It was removed from the left orbit during preparation.
**Pectoral Girdles and Fins.** — The left girdle consists of the proximal portion of the posttemporal, a complete coracoid, a nearly complete cleithrum that is missing the dorsal and posterior processes (terminology of Wapenaar and Talbot, 1964), and a nearly complete scapula that is lacking the articular surface for the first pectoral ray. The oval scapular foramen measures 22 mm long and 13.6 mm wide. The massive left first pectoral ray is incomplete proximally and distally. It measures 235 mm in length and 106.2 mm across its proximal articulating surface (base). The second radial was identified among the associated fragments.

The right pectoral girdle and fin are nearly complete (Figs. 3–5). The distal supracleithrum is in articulated position with the cleithrum. The cleithrum lacks just the anterior dorsal process and a portion of the posterior dorsal process. The coracoid is complete and the scapula is entire except for the portion that articulates with the radials.

The right pectoral fin was initially found articulated with the pectoral girdle and was in an abducted (extended) position, i.e., sticking out laterally from the body. The fin was deliberately removed during the preparation process in order to study the diagnostic articulation surfaces between the scapula and first ray. It appears that the articulation surface (facet) on the scapula for the first pectoral ray is limited to the lateral surface of the scapula and is flat. Postero-dorsally to this facet there are one or possibly two foramina. The scapula in HLF-106 (black marlin) has two foramina in this position, whereas the scapula in BRUNN 563-60 (blue marlin) lacks foramina.

The right pectoral fin (Figs. 3–5) is composed of 21 rays and measures 162 mm wide across the base of the fin rays. The first ray is massive and is 120 mm across the widest part of its base. The portion of the articular surface (facet) that was presumably covered with cartilage to form a diarthrosis with the scapula, makes
Figure 6. Neurocranium of black marlin (*Makaira indica*), Early Pleistocene, Tambac Island, Philippines. A. Dorsal view. B. Lateral view. C. Ventral view. Scale equals 10 cm. Letters indicate: anterior articular process of hyomandibula (H), maxillary (M), orbit (O), palatine (PAL), vomer (VO).
up approximately one-fourth of the total surface area of the proximal base of the first ray (Fig. 5). There is a large posteriorly directed flange on the base of the first ray that arches over the posterodorsal surface of the scapula. In HLF-106 (black marlin) the first ray has a similar surface area devoted to the scapular facet and the base of the first ray has a large posteriorly directed flange. In BRUNN 565-60 (blue marlin), a much larger fish than HLF-106, the scapular facet on the first ray is approximately one-half of the surface area of the proximal base of the first ray and the posteriorly directed flange is smaller.

Of the four radials, the first is partially covered by the articular surface of the scapula, the second is the most stout, and the fourth is the longest (88 mm). There is a large foramen between the third and fourth radials.

Pelvic Girdles (Basipterygia) and Fins. — Both pelvic girdles are complete except for the distal portion of the posterior styliform process and the anterior and posterior margins of the central part (terminology from Collette and Chao, 1975 and Potthoff, 1980). During preparation we exposed only the left girdle and it is 189 mm from the tip of the anterior process to the fin ray facet.

The pelvic fins consist of the right pelvic spine and the proximal portion of the two rays of both sides.

Rostrum. — It consists of six fragments (not figured), the longest measuring 333 mm. Unfortunately, pieces of the rostrum were collected by local amateurs who used them as sharpening stones for their bolo knives, resulting in most of the denticles being worn away. All fragments had been split lengthwise so that the cross-sectional shape and the number, size and position of nutrient canals could not be determined.

Breast Scales and Other Features. — Scales were well-preserved over the pectoral girdle posterior to and beneath branchiostegal rays. Many were removed during preparation and all appear to resemble an irregular flat toothpick, i.e., blunt and wide anteriorly and tapering to a single point posteriorly. Some scales are 55 mm long and 5 mm wide. This morphology, except for size, compares well with a sample from the breast region of a recent black marlin (HLF-112). A similar sample from the breast region of a recent blue marlin (HLF-111) has some scales unbranched, but others becoming bifid or trifid posteriorly.

Beneath and between the branchiostegal rays are fine, regular, thin laminae of bone, approximately 1 mm apart. We interpret these structures as gill rays. Also located beneath the branchiostegal rays of the right side are two groups of three vertebrae (each measuring approximately 16 mm in length). They appear to represent a single bony fish specimen that was “swallowed” tail first. In the portion of the fossil black marlin specimen containing the ceratohyal and hypohyal (not figured), there are several fragmentary abdominal vertebrae and a badly preserved neurocranium which we assume to be the anterior part of the specimen found in the posterior branchial cavity.

DISCUSSION

Identification. — There is little doubt that the Tambac Island fossil is a black marlin (M. indica). Its general resemblance to other istiophorids, large size, acute parasphenoidal angle, and rigid pectoral fin are diagnostic features for the species (Fierstine, 1978; Nakamura, 1974; Robins and de Sylva, 1960). However, anytime one studies fossils which are imperfect, bony structures must be interpreted. Also, not enough is known about the comparative osteology of recent istiophorids to know sometimes what is individual or specific variation.
Size.—There are no studies relating skull characters and size of marlins. When the size of the fossil neurocranium is compared with another from a 328 cm fork length blue marlin (BRUNN 565-60), then it is conservatively estimated that the fossil must have had a fork length of at least 350 cm. Using the length-weight curves given by Strasburg (1969), then the fish must have weighed over 455 kg. We did not compare the fossil with a black marlin because no large black marlin neurocranium with length or weight data was available to us. The length-weight relationship of the blue and black marlins is approximately similar. Apparently only females attain this large size (Nakamura, 1975).

ZOOGEOGRAPHY OF ISTIOPHORID BILLFISHES

Extant Species.—The family Istiophoridae contains three genera and nine generally recognized species. All inhabit tropical and/or temperate marine waters. Seven species have restricted ranges, whereas two species are distributed worldwide. Only the genus Makaira will be discussed here.

The genus Makaira has two generally recognized species: M. indica (black marlin) and M. nigricans (blue marlin). Nakamura et al. (1968) divide the blue marlin into an Atlantic (M. nigricans) and an Indo-Pacific (M. mazara) species. The blue marlin ranges from about lat. 45°N to 40°S in the Atlantic Ocean and from about lat. 48°N to 48°S in the Pacific (Rivas, 1975). In the Indian Ocean, the blue marlin ranges from lat. 45°S in the west to 35°S in the east. The black marlin is distributed primarily in the Indo-Pacific Ocean from about lat. 40°N to 45°–50°S (Nakamura, 1974 and 1975). Occasional strays do occur in the Atlantic Ocean presumably by way of the Cape of Good Hope.

Post-Oligocene Fossils.—Fossil istiophorids are assigned to only two extant genera, Istiophorus and Makaira. Fierstine (1978) considers all fossils placed in Istiophorus to be arbitrary decisions and that they should just be considered members of the family Istiophoridae. There is no evidence that they are closely related or identical to the sailfish. Identifications have been based on fragments (usually rostra) which lack meaningful comparison with living species.

The pre-Miocene species of Istiophorus are so different or fragmentary that their true identification may never be known. We will only consider distribution of the post-Oligocene species: I. homalorhamphus (Cope, 1869) from the Eocene or Miocene of New Jersey, U.S.A.; I. calvertensis Berry, 1917, from ?Miocene of Virginia, U.S.A.; I. robustus (Leidy, 1860) from ?Pliocene of South Carolina, U.S.A.; I. teretirostris (Van Beneden, 1871) from ?Middle Miocene of Belgium; I. belgicus (Leriche, 1926) from ?Pliocene of Belgium; I. vanbenedensis (Lawley, 1876) from Lower Pliocene of Italy; and I. courcelli (Arambourg, 1927) from Lower Pliocene of Algeria. Except for the specimens in Belgium, all fossil forms are well within the current range of living billfishes. When one considers the climate during the Miocene and Pliocene, the Belgian fossils are within the expected distribution (Schwarzbach, 1961).

The genus Makaira has been positively identified in southern California during the Miocene and Pliocene (Fierstine and Applegate, 1966; Fierstine, unpublished data), in Virginia during the Miocene (Fierstine, unpublished data), in Panama as M. panamensis Fierstine 1978 during the Late Miocene, in Italy as M. nigricans (=Istiophorus herschelii) during the Pliocene (Barbolani, 1910) and now in the Early Pleistocene of the Philippines as M. indica. All fossil discoveries are well within the expected post-Oligocene range of distribution except for those in Italy.
No extant specimens of blue marlin are known from the Mediterranean Sea. Perhaps these specimens were trapped following the closing of the ancient Tethys sea-way or they could have been strays from the Atlantic Ocean.

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LITERATURE CITED


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